Faculty of Mechanical Engineering

SOUND RADIATION FROM VIBRATING PLATE WITH DIFFERENT BOUNDARY CONDITIONS USING DISCRETE SOURCE TECHNIQUE

Nurain Shyafina binti Ab. Latif

Master of Science in Mechanical Engineering

2016

SOUND RADIATION FROM VIBRATING PLATE WITH DIFFERENT BOUNDARY CONDITIONS USING DISCRETE SOURCE TECHNIQUE

NURAIN SHYAFINA BINTI AB. LATIF

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this thesis entitled "Sound radiation from vibrating plate with different boundary conditions using discrete source technique" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering

Signature	: ....
Supervisor Name	: ....
Date	: ....

"To my beloved parents"

ABSTRACT

The study of sound radiation from vibrating plate is an important subject in acoustic and being widely explored throughout years. The aims of this thesis are first to develop sound radiation model from a vibrating plate using discrete elementary source for different boundary conditions such as free-free, simply-supported and clamped-clamped. Secondly, the aim is to validate the radiation efficiency model between the proposed method and the experimental data. Analytical models of the sound radiation a rectangular plate are often based on simply supported edges for its mathematical convenience. Models for other boundary conditions also exist, but mostly these employ rather complicated analytical calculations. This study presents a mathematical model of the radiation efficiency for a baffled plate using a discrete elementary source model. The plate velocity from each element on the plate has been determined from Finite Element Analysis (FEA) then was inserted into MATLAB for radiation efficiency calculation. The model requires only the knowledge of the spatial distribution vibration velocity of the panel and hence, the surface velocity can be calculated conveniently by using the established mobility equations for different boundary conditions. The model from FEA has validated with theoretical model. After the validation, which the model from FEA shows good agreement with the theoretical model, then the radiation efficiency can be determined using velocity data from FEA modeling. For validation, the experiment was done in small chamber and reverberation chamber. The sound power was measured using reciprocal technique because of its convenient (time efficient, less cost) compared to direct method which needs the use of shaker. The experimental results are presented for free-free and clamped-clamped boundary conditions which show reasonable agreement with the predicted results. On the basis of the results of this research, it can be concluded that the clamped-clamped boundary condition has the highest radiation efficiency compared to free-free and simply-supported boundary conditions. The model to calculate the radiation efficiency from vibrating plate using discrete elementary source has been successfully modeled and validated with the experimental data.

ABSTRAK

Model analisis radiasi bunyi plat segi empat tepat biasanya adalah berdasarkan bahagian sempadan plat yang disokong untuk memudahkan pengiraan matematik. Model untuk keadaan sempadan yang lain juga wujud, tetapi kebanyakannya mengunakan analisis pengiraan yang rumit. Kajian ini membentangkan model analitikal kecekapan radiasi bunyi untuk plat menggunakan model sumber asas diskrit. Halaju plat untuk setiap elemen plat telah dikira dari Analisis Elemen Takterhingga (FEA) kemudian dimasukkan ke dalam MATLAB untuk pengiraan kecekapan radiasi. Model ini memerlukan pengetahuan halaju getaran untuk taburan ruang panel dan seterusnya, halaju permukaan boleh dikira dengan mudah dengan menggunakan persamaan kebolehgerakan yang diwujudkan untuk keadaan sempadan plat yang berbeza. Model daripada FEA telah disahkan dengan model teori. Selepas pengesahan dibuat yang mana model daripada FEA menunjukkan keputusan yang baik dengan model teori, kecekapan radiasi bunyi menggunakan model sumber asas diskret boleh ditentukan. Untuk pengesahan antara eksperimen dan model yang dicadangkan, eksperimen telah dijalankan di kebuk kecil dan kebuk penggemaan besar. Tekanan bunyi diukur menggunakan teknik timbal balik disebabkan caranya yang lebih mudah dan ringkas berbanding teknik pengukuran secara langsung yang memerlukan penggunaan penggetar. Pengesahan antara keputusan ekperimen dan model yang dicadangkan telah dibuat dan ditunjukkan dalam kajian ini. Keputusan eksperimen yang ditunjukkan oleh plat keadaan sempadan bebas dan plat keadaan sempadan terkapit menunjukkan kuputusan yang munasabah dengan keputusan yang dijangkakan daripada model yang dicadangkan. Sebagai kesimpulan, plat dengan keadaan sempadan terkapit menunjukkan kecekapan radiasi bunyi yang paling tinggi berbanding dengan plat keadaan sempadan bebas. Model untuk mengira kecekapan radiasi bunyi menggunakan model sumber asas diskret telah berjaya dihasilkan dan disahkan dengan keputusan eksperimen.

ACKNOWLEDGEMENTS

In the name of Allah, The Beneficent, The Merciful

This research was made possible through contributions, support, and encouragement from many individuals. Unfortunately, it is not possible to acknowledge each of them here. First and foremost , I would like to thank ALLAH SWT for the blessing and ability given to me to eventually complete my Master thesis . I would like to give sincere tribute to my supervisor, Assoc. Prof. Dr. Azma Putra for everything. From preliminary ideas to data processing, invaluable guidance, continuous encouragement, and excellent supervision in making this research possible. I really appreciate the consistent support he provided me throughout the research. The good advise, support, and friendship of my second supervisor, Mr. Hairul bin Bakri has been invaluable on both academic and personal level for which I am extremely grateful.

I wish to express my gratitude towards my parents, Ab. Latif bin Ab. Majid and Asmah binti Surip, for their unlimited love. It is because of their prayer that I have become what I am. I could not find a appropriate words that could properly describe my appreciation for their devotion, support, and faith in pursuing my dreams.

Also not to forget staff in the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka and Faculty of Engineering and Built Environment of Universiti Kebangsaan Malaysia, Bangi which their names are too numerous to mention, who help me directly or indirectly throughout the whole project. For my colleagues in 'Acoustics and Vibration Group', thank you for the brilliant discussion which gives much input to my work.

Finally and most importantly, to all my friends that always encourage me to never give up in my study and always being good friends throughout my 4 years here.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE	TITLE	PAGE

LIST OF ABBREVIATIONS

FEA	**F**inite **E**lement **A**nalysis
FFT	**F**ast **F**ourier **T**ransform
SPL	**S**ound **P**ressure **L**evel
kHz	**k**ilo **H**ertz
CAD	**C**omputer **A**ided **D**esign

LIST OF PHYSICAL CONSTANT

Speed of sound	c_o	$=$	343 ms^{-1}
Density of the air	ρ	$=$	1.2 kgm^{-3}
Density of aluminium	ρ_{al}	$=$	2700 kgm^{-3}
Poisson's ratio of aluminium	ν	$=$	0.334
Young's Modulus of aluminium	E	$=$	7.1×10^{10} Nm^{-2}

LIST OF SYMBOL

a	Length of panel
b	Width of panel
E	Young's modulus
F	Force
h	Thickness of plate
$i, j = \sqrt{-1}$	Imaginary unit
I	The second mass moment inertia of the structure
k	Acoustic wavenumber
M	Total mass of panel
m	Odd modes
n	Even modes
Re	Real part
v	Velocity
v_p	Plate velocity
W	Radiated power
Y_p	Point mobility
Y_t	Transfer mobility
$\left\langle \overline{v^2} \right\rangle$	Spatial average of mean-squared velocity
ω	Angular frequency or natural frequency
ρ	Density
η	Damping loss factor
ν	Poisson's ratio
φ	Relative phase
λ	Wavelength
ϕ, θ	Phase
μ	Mean

σ	Sound radiation
Φ	Normalised mode shape

LIST OF PUBLICATIONS

Proceedings

A. Putra, N. Muhammad, N. Shyafina, and D. J. Thompson, Radiation Efficiency of a Perforated Panel Modelled Using Elementary Source Technique. In Proceedings of the 20th International Congress on Sound Vibration (pp. 1-8) (2013). *International Institute of Acoustics and Vibration*.

A. Putra, N. Shyafina, N. Muhammad, H. Bakri and N. F. Saari . Development of Hybrid Semi-Analytical and Finite Element Analysis to Calculate Sound Radiation from Vibrating Structure. Advanced Materials Research (Vol. 845, pp. 71-75) (2014).

A.Putra, N. Shyafina, D. Thompson, N. Muhammad , M. Jailani M. NOR, and Z. Nuawi ,Modelling sound radiation from a baffled vibrating plate for different boundary conditions using an elementary source technique. In INTER-NOISE and NOISE-CON Congress and Conference Proceedings (Vol. 249, No. 1, pp. 5812-5819) (2014, October). *Institute of Noise Control Engineering*.

N.Shyafina, A. Putra, Z. Y. Lim, and N. Muhammad,Reciprocity method in a small acoustic space to measure sound radiation from baffled perforated plates. *Proceedings of Mechanical Engineering Research Day 2015: MERD'15*, 101-102 (2015).